

## THE ROLE OF REGOLITH ADSORPTION IN THE TRANSITION FROM EARLY TO LATE MARS CLIMATE

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The total degassed  $\text{CO}_2$  inventory on Mars is currently thought to be the equivalent of about 3.0 bars or less (1). Using a surface pressure of ~1 bar, several radiative transfer models for early Mars have been advanced (2) purporting to show that a significant greenhouse effect could have characterized the early Mars environment, possibly explaining the intense channeling of the most ancient Mars terrain.

We have reexamined those models with regard to the effect that regolith adsorption may have had. In our model, we take into account: 1) the atmospheric greenhouse effect, 2) the existence, mass, and temperature of any cap, 3) the partition of  $\text{CO}_2$  between the atmosphere-cap system and the regolith as required by the latitudinal temperature distribution, and 4) atmospheric heat transport.

We solve simultaneously for all these interdependent variables for cases involving realistic total  $\text{CO}_2$  inventories, a variety of published greenhouse models, and both current and lower solar constants.

To describe regolith adsorption properties we use the mineralogically insensitive adsorption relationship developed by Zent et al. (3), which is normalized to be consistent with observed surface properties of Viking-sampled soil (4). We should point out that adsorption is relatively more effective under current Martian conditions than at the higher temperature and pressure conditions that may have characterized the early Martian environment. However, the regolith currently has adsorbed 10 - 100 times the atmospheric  $\text{CO}_2$  inventory, whereas in most models the removal of only half the original atmospheric  $\text{CO}_2$  inventory would be sufficient to destroy the strong greenhouse effect.

Resulting scenarios fall into several classes. Either: 1) The greenhouse effect is so weak that a cap exists throughout the period of growth of several hundred meters of regolith. In this case the surface environment is essentially unaffected by the development of any reasonably postulated regolith; or 2) A cap exists initially, but is sufficiently small that the growth of >100m or so of regolith causes a significant repartitioning of  $\text{CO}_2$  molecules among the three parts of the system and the equilibrium solution finally involves no cap. In this case the regolith has no effect on the atmospheric pressure and resulting temperatures until the cap disappears. However, once the cap disappears, the effect of further regolith growth is to dramatically lower atmospheric pressure and hence surface temperatures; or 3) A substantial greenhouse effect exists initially, and there is no cap initially. In this case, also, regolith growth to a depth of several hundred meters dramatically lowers atmospheric pressures and surface temperatures, and the effect of the regolith is important from the outset.

In all scenarios which start out with surface pressures on the order of 1 bar, high pressures and temperature conditions are truncated by the growth of only a few hundred meters of regolith, ultimately leading to present Mars conditions. It might be argued that while the development of a regolith a few hundred meters thick in early Mars history is likely in view of the existence of the ancient cratered terrain, it is unreasonable to postulate a much lower regolith thickness at the very outset. We point out, however, that it is not literally the thickness of the regolith that is the critical parameter, but rather its total surface area. Weathering products such as palagonites and nontronites typically exhibit specific surface areas for  $\text{CO}_2$  adsorption of tens to

hundreds of square meters per gram, whereas basalts typically exhibit specific surface areas of a fraction of a square meter per gram to several square meters per gram. Thus, although we represent the "regolith growth" as a physical thickening (keeping the specific surface area equal to the Viking derived value), the actual case involves the product of both actual thickening and a great increase due to an increased abundance of weathering products. While the precipitation of carbonates has probably been an important process during Mars history (5), the rates at which this process could have taken place under early Mars conditions would have dropped sharply once liquid water was fairly scarce. Furthermore, conditions under which liquid water was available may have involved efficient recycling of carbonate so that steady state conditions rather than irreversible  $\text{CO}_2$  removal prevailed. In contrast, the growth of regolith surface area demands corresponding and predictable  $\text{CO}_2$  removal from the atmosphere-cap system and is, as shown here, fully capable of terminating any enhanced temperature regime on early Mars in the absence of any other effects. To put it another way, total degassed  $\text{CO}_2$  inventories of <2 bars and the existence of substantially higher temperatures than present are compatible; total degassed  $\text{CO}_2$  inventories of <2 bars, substantially higher temperatures than present, and a regolith qualitatively comparable to the present one are not compatible.

More recent calculations (6) have shown that when reduced solar radiation is taken into account ~5 bars of  $\text{CO}_2$  is necessary to raise average surface temperatures on Mars above freezing. Calculations are presently under way to determine the effect of regolith adsorption in the evolution of this large amount of atmospheric  $\text{CO}_2$ .

#### REFERENCES

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